Polarization sensitive solar-blind detector based on *a*-plane AlGaN.

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Abstract

We report polarization-sensitive solar-blind metal-semiconductor-metal UV photodetectors based on $(11\bar{2}0)$ *a*-plane AlGaN. The epilayer shows anisotropic optical properties confirmed by polarization-resolved transmission and photocurrent measurements, in good agreement with band structure calculations.

Solar blind UV (SBUV) detectors, with no photosensitivity above 280nm wavelength, have wide range of applications like – missile plume detection, UV astronomy, chemical/biological battlefield reagent detection etc.[1–3]. The wide-bandgap, high-temperature compatible AlGaN material system has been the workhorse for such SBUV detectors with many reports on high performance devices based on [0001] *c*-plane AlGaN layers. The inherent anisotropic optical properties and reduced crystal plane symmetry of "non-polar" $(11\bar{2}0)$ *a*-plane AlGaN epilayers allows the fabrication of polarization sensitive (PS) detectors. Such PS detectors give additional advantages of selectivity and narrow band detection in a differential configuration consisting of two or four photo-detectors, without using filters [4,5]. We present, to the best of our knowledge, the first report of a PS SBUV detector.

About $0.5\mu m$ thick $Al_{0.6}Ga_{0.4}N$ epilayers were grown on AlN buffer layers via metal organic vapour phase epitaxy (MOVPE) in a closed-coupled showerhead reactor using standard precursors. The details of the growth procedure, method to estimate the solid phase Al content and strain in the layer can be found in Refs.[6,7]. Metal-Semiconductor-Metal (MSM) type devices with interdigitated finger geometry Schottky contacts (metallization–200$\AA$ Ni/1000$\AA$Au) were fabricated using standard optical photolithography, electron-beam evaporation and lift-off techniques.

The III-nitride semiconductors have three closely-spaced valence bands near the center of

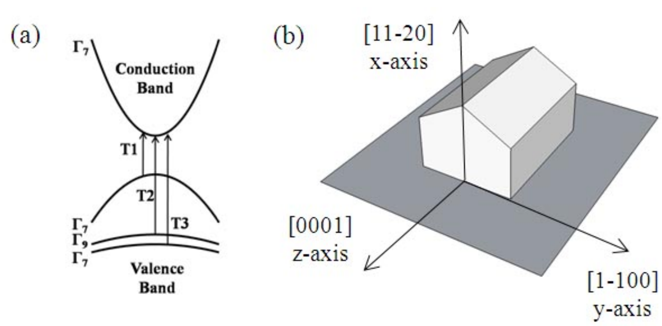

Figure 1: (a) Schematic diagram showing the three closely spaced valence band at k=0 of the III-nitrides. (b) Orientation of hexagonal unit cell for *a*-plane nitrides. The in-plane strains are ϵ_{yy} and ϵ_{zz}.

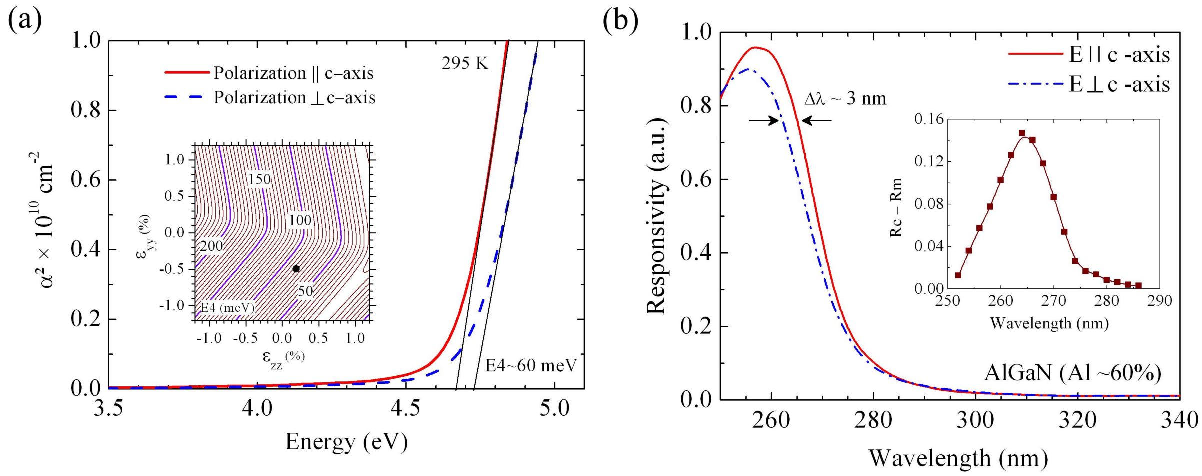

Figure 2: (a) Optical absorption spectra of a-plane $Al_{0.6}Ga_{0.4}N$ showing difference in bandgap $E_4 \approx 60$ meV for two different polarizations, Inset: calculated E_4 as a function of in-plane strains, black dot represent the strain in our layer for which the calculated value is ~ 80 meV (b) Polarization resolved photocurrent measurement for $E \parallel c$ and $E \perp c$ polarization, confirming polarization sensitivity with sharp cut-off below 280 nm. Inset: different in responsivity as a function of wavelength.

the Brillouin-zone (k=0) as shown in Fig.1(a). The transition probabilties of electrons from each valence band to the conduction band are different and are strongly determined by the polarization of light. For $(11\bar{2}0)$ a-plane epilayers, the in-plane strains are ϵ_{yy} and ϵ_{zz} as shown in Fig.1(b). Using HRXRD we estimate the in-plane anisotropic strain in our $Al_{0.6}Ga_{0.4}N$ epilayer as $\epsilon_{yy}=-0.5\%$ and $\epsilon_{zz}=+0.2\%$, for which $E1$ transition is strongly **z**-polarized and $E2$ transition is strongly **y**-polarized, obtained from the band structure calculation by solving the *Bir-Pikus* Hamiltonian [8,9].

Fig.2(a) shows the absorption spectra of $Al_{0.6}Ga_{0.4}N$ for two different polarizations, where the extrapolation of α^2 vs. *energy* plot gives the bandgaps of the epilayer as $\sim$4.67 eV and $\sim$4.73 eV for $E \parallel c$ and $E \perp c$ polarization directions respectively. So the valance band splitting E_4=$E2$-$E1$ is $\approx$ 60 meV. Fig.2 (a) inset shows the calculated E_4 as a function of in-plane strain and the the black dot represents the strain in the layer. The experimentally obtained value of E_4 fairly matches with the value 80 meV obtained from calculation.

The polarization-resolved photocurrent measurement on the device (geometry: finger width 10μm and gap 10μm; bias voltage=10 V) fabricated on $Al_{0.6}Ga_{0.4}N$ shows different responsivity spectra Rc and Rm for different in-plane polarization $E \parallel c$ and $E \perp c$ respectively, as shown in Fig.2(b). Inset shows the difference in responsivity ($Rc - Rm$) as a function of wavelength. It shows a peak at $\sim$265 nm with peak responsivity of $\sim$15% to the maximum responsivity Rc and FWHM of $\sim$10nm. The UV to visible rejection ratio is 10^2. The polarization sensitivity contrast (Rc/Rm) is about 1.2. Both the spectra shows cut-off below 280nm, fulfilling the solar-blind criteria, and making this perhaps the first demonstration polarization sensitive SBUV detectors reported so far.

In conclusion, we have successfully demonstrated polarization-sensitive SBUV detectors fabricated on non-polar a-plane AlGaN. Such devices will be helpful for civil and strategic applications.

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